Modelling of Nearshore Wave, Current and IG-Wave Motion

Ib A. Svendsen
Center for Applied Coastal Research
University of Delaware
Newark, DE 19716
Phone (302) 831-2449; Fax (302) 831-1228 email: ias@coastal.udel.edu

James M. Kaihatu
Ocean Dynamics and Prediction Branch, Oceanography Division
Naval Research Laboratory
Stennis Space Center, MS 39529-5004
Phone (228) 688-5710; Fax (228) 688-4759 email: kaihatu@nrlssc.navy.mil

Award Number: N00014-99-1-0291
Document Number: N00014-00-WX20849
Document Number: N00014-00-WX20850

LONGTERM GOAL

The long-term goal is to develop accurate and efficient models for the dynamics of nearshore processes. The model development is to be done in such a way as to render the completed model useful in operational contexts. This will involve the use of data assimilation in order to enhance the accuracy of forecasts.

OBJECTIVES FOR THE PROPOSED WORK

The present work is contributing to the long-term goal by testing and further developing the capabilities of the SHORECIRC circulation model system. This includes work on three different groups of tasks

1. Model Testing and Verifications.
2. Model Developments and Analysis
3. Application Oriented Developments

Each of those are in one way or the other oriented toward bringing the SHORECIRC (SC) model on a form where it can be used on a more routine basis by other users, including Naval operations planners.

APPROACH

This project is a collaborative effort between the Center for Applied Coastal Research (CACR), University of Delaware, and The Naval Research Laboratory (NRL), Stennis, Mississippi with Dr. Kaihatu (COPI) and his group.

Report Documentation Page

Form Approved
OMB No. 0704-0188

1. REPORT DATE **30 SEP 2001**	2. REPORT TYPE	3. DATES COVERED **00-00-2001 to 00-00-2001**

4. TITLE AND SUBTITLE **Modelling of Nearshore Wave, Current and IG-Wave Motion**	5a. CONTRACT NUMBER
	5b. GRANT NUMBER
	5c. PROGRAM ELEMENT NUMBER
6. AUTHOR(S)	5d. PROJECT NUMBER
	5e. TASK NUMBER
	5f. WORK UNIT NUMBER
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) **Center for Applied Coastal Research,University of Delaware,,Newark,,DE, 19716**	8. PERFORMING ORGANIZATION REPORT NUMBER
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)	10. SPONSOR/MONITOR'S ACRONYM(S)
	11. SPONSOR/MONITOR'S REPORT NUMBER(S)

12. DISTRIBUTION/AVAILABILITY STATEMENT
Approved for public release; distribution unlimited

13. SUPPLEMENTARY NOTES

14. ABSTRACT
The long-term goal is to develop accurate and efficient models for the dynamics of nearshore processes. The model development is to be done in such a way as to render the completed model useful in operational contexts. This will involve the use of data assimilation in order to enhance the accuracy of forecasts.

15. SUBJECT TERMS

16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
a REPORT **unclassified**	b ABSTRACT **unclassified**	c THIS PAGE **unclassified**	**Same as Report (SAR)**	**8**	

WORK ON MODEL DEVELOMENT

Reference Version of the Model System

Work on development of a reference version 1.3.6 of the model was a top priority for the project. This work was essentially completed last year, and both the code and a manual that describes this version was made available to the NOPP group of PI's for testing and commenting.

Since then work has been done on maintenance and debugging of the reference version. Numerous bugs and suggestions for improvement has been received and implemented in the 1.3.7 version. In addition a significant modification listed as version 2.0 has been implemented.

The plan for finalization of this project component is to place the SHORECIRC model system version 2.0, which consists of a modified version of the REFDIF wave driver and the circulation component, on the CACR web site to make it available to registered users in the general scientific and engineering community. The website will include an online version of the code and the manual. This step is expected to be finished before the end of the year 2001.

This will also include issuing the manual for the model as a Center for Applied Coastal Research (CACR) research report (Svendsen et al, 2001).

Analysis of instability for wave current interaction

In the process of the work with the reference version we discovered, that under certain conditions with wave current interaction active in the computations, the model developed a peculiar and very non-physical current pattern with stationary vortices that grew very slowly in time, but did not propagate, even with a strong longshore current. A temporary solution to this problem was introduced last year. Work continued however, and led to the more significant revision now available as version 2.0. This includes redefining some of the variables in the model including the depth-averaged velocity.

In addition a further expanded version of the code has been developed under the NOPP project for "Development and verification of a comprehensive community model for physical processes in the nearshore ocean." This version, which eventually is expected to become the reference version includes the possibility also to operate the model on a general non-orthogonal curvilinear grid, is still under testing and will be part of the NOPP community model.

ANALYSIS OF NEARSHORE FLOW PEHENOMENA

Effect of Errors in the Cross-shore Boundary Conditions

One of the major problems in ocean modelling is that information generally is not available for a correct specification of the model boundary conditions. This has practical importance because in real applications we hardly ever have enough information about the flow coming into the modelled domain from the region outside the model domain where conditions in principle are unknown.

Work reported last year on this topic has been continued with analysis of the effect of the position of the offshore boundary. It was found that in particular i cases where the total volume flux over the upstream boundary was overestimated, the total flux error would increase inside the domain creating

increasingly large artificial recirculation flows which are influenced by the position of the offshore boundary. The work is being published as Chen and Svendsen (2001a,b).

3-D effects on shear wave instabilities

Since the discovery by Oltman Shay et al. (1989) that in nature longshore currents often exhibit unstable behaviour in the form of undulations this phenomenon, which has been termed shear wave instability, has been widely studied in the literature by means of numerical modelling. These studies, such as Bowen and Holman, (1989), Dodd and Thornton (1990), Dodd et al. (1992), Falques and Iranzo, (1994), Falques et al. (1994), Allen et al. (1996) Özkan-Haller and Kirby (1999), and Slinn et al. (1998) to mention some, were, however, all conducted on the basis of the depth uniform nonlinear shallow water equation of slightly modified version of those equations. An exception is the work by Putrevu et al. (1998) which analyzed the effect of the 3-D current structure which has also been found responsible the major part of the lateral mixing in the nearshore (Svendsen and Putrevu (1994) and others).

Interesting work has been done under this grant to analyze how inclusion of the 3-D current structure, which is an essential feature of the SC model system, influences the conclusions of earlier investigations on shear wave generation and development. The results are very complex but generally show that the 3-d effects greatly reduce the risk of instability of the current and play an important role in the development of the shear waves once generated. Hence this is another example where the results found by neglecting the 3-D effects may be misleading because the 3-D effects change the entire nature of the flow pattern. Zhao and Svendsen, (2001a,b).

Comparison with field data

Work on comparison of model simulations with field data has continued. Specifically results for comparisons with data from the SandyDuck97 experiments have been performed for a series of three-hour averaged current distributions. In order to avoid excessive errors from insufficient information about conditions along cross-shore boundary discussed above the model simulations are performed over the maximum region surveyed by the CRAB. The results therefore show a much larger section of the coast than the region actually covered with sensors during the experiment. Fig. 1 shows an example of the 3-hour averaged measured velocities for the situation on October 17, 1997, 0100-0400 and Fig. 2 shows the computed velocities in the same period. The computations cover a much larger domain than the measurements but it is seen that the velocity field in the area of the measurements is very similar. Further work on this in continued under the NOPP project.

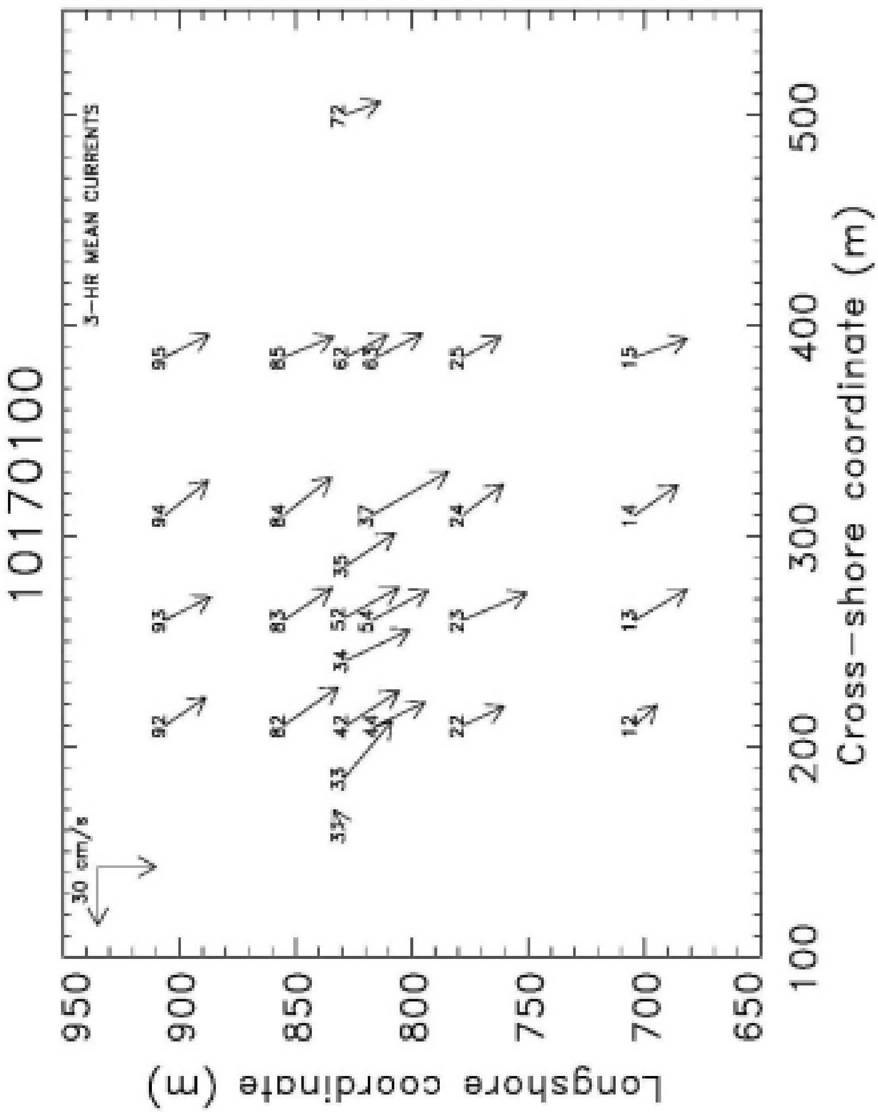

Figure 1: Measured 3-hour averaged velocities at the SandyDuck97 experiment on Oct 17 1997 0100 - 0400.

Parallel version of the computer code

One task within the project was to investigate the parallelability of the SHORECIRC code as presently written. Loop-level, coarse-grained MPI commands were inserted into the code and the speedup investigated. It was determined that this level of code parallelization (most amenable to compiler-time auto-optimization) was insufficient to offer significant speedup, and that a fine- grained parallelization would be required. This would entail a deep rewrite of the code. We note here that a proposal submitted to the Parallelization Environment and Training (PET) program by personnel at the University of Southern Mississippi addresses performing this parallelization of the SHORECIRC code;

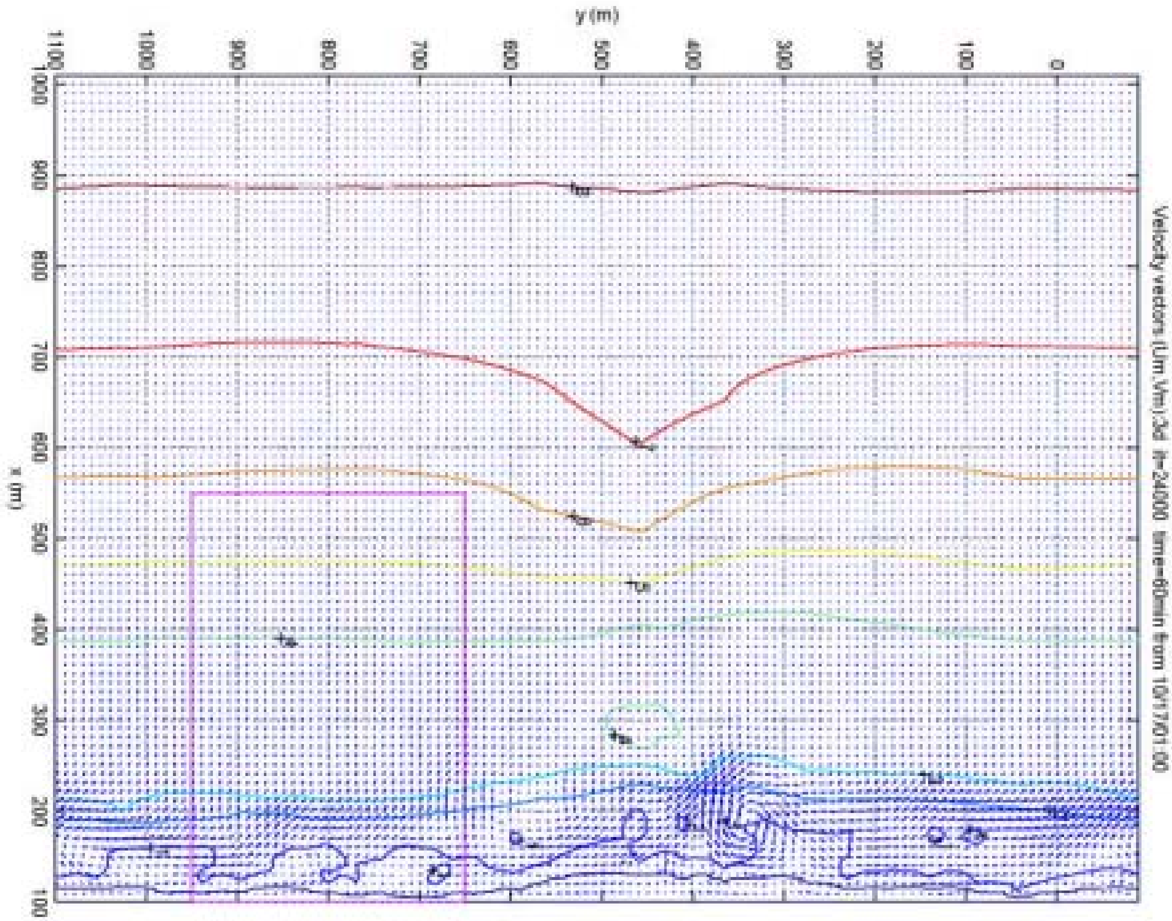

Figure 2. 3-hour averaged velocities computed using the quasi-3D SHORECIRC model system at the SandyDuck97 experiment on Oct 17 1997 0100 - 0400. The region covered by the measurements is marked by the rectangle. The Duck Pier is around y = 700m.

this proposal has been approved for funding. Thus, within the next three years, a workable parallelized SHORECIRC code will be available. This work was undertaken at NRL, Stennis.

RESULTS

Results from the work are published in Zhao and Svendsen (2001a,b,c) and in Chen and Svendsen (2001a,b).

IMPACT

The results of the work done will contribute to the reliability of the model and help bringing it to use in practical cases such as planning of naval operations and coastal engineering problems.

TRANSITIONS

The SC-model is a central element in the planned community model under development in the NOPP project "Development and verification of a comprehensive community model for physical processes in the nearshore ocean". Within that project the model-system has been passed on to several people. In addition to one of the PI's on the present project, Dr James Kaihatu who has conducted both extensive analysis and further development of the model, Dr Dan Hanes, University of Florida, Gainesville, Dr Tom Drake, North Carolina State, University, and Dr. Tuba Özkan-Haller, University of Michigan (now Oregon State University), all members of the NOPP-group of PI's, have requested and received a copy of the code as well as the manual, and contacts about updates toward the reference version now available have been maintained. In addition Dr Daniel Conley, University of New York at Stoney Brook as well as Dr Jane Smith at WES have requested and received code and manual. The model is being used by the staff at the US Army Corps of Engineers Large Scale Sediment Transport Facility at Engineer Research and Development Center, Vicksburg, for analyzing the flow in the facility and measurements, and also by others at the center. It is used by Dr Jerry Milgram, MIT in an ONR funded project on unmanned underwater vehicles

RELATED PROJECTS

"Development of coastal profiles on a sandy coast." PI: I. A. Svendsen Sponsor: NOAA/Sea Grant

"The generation of rip currents and circulation around coastal structures" Sponsor: NOAA, Sea Grant

"Surf and surf zone hydrodynamics" PI: Peregrine, CoPI: Svendsen Sponsor: ONR NICOP

"Development and verification of a comprehensive community model for physical processes in the nearshore ocean".
PI'S: Kirby, Svendsen (at UD, and others outside UD) Sponsor: NOPP

"A computational model for the hydrodynamical and littoral processes at the large-scale sediment transport facility at WES" PI: Svendsen Sponsor: ARO

REFERENCES

Allen J. S., P. A. Newberger, and R. A. Holman (1996). Nonlinear shear instabilities of alongshore currents on plane beaches. *J. Fluid Mech.*, 310:181-213.

Bowen, A.J. and R.A. Holman, (1989). Shear instabilities of the mean long-shore-current. 1. Theory. *J. Geophys. Res-Oceans*, 94:(C12), 18023-18030.

Dodd, N. and E. B. Thornton (1990). Growth and energetics of shear waves in the nearshore. *J. Geophys. Res-Oceans*, 95:(C9), 16075-16083.

Dodd, N., J. Oltman-Shay, and E. B. Thornton (1992). Shear instabilities in the long-shore-current - A comparison of observation and theory. *J. Phys. Oceanogr.*, 2:(1) 62-82.

Falques, A. and V. Iranzo, (1994). Numerical-simulation of vortices waves in the nearshore. *J. Geophys. Res-Oceans*, 99: (C1) 825-841.

Falques, A., V. Iranzo, and M. Caballeria (1994). Shear instability of longshore currents: Effects of dissipation and non-linearity. In *Proc. 24th Int. Conf. Coastal Engng*., 1983-1997.

Oltman-Shay, J., P.A. Howd and W.A. Birkemeier, (1989). Shear instabilities of the mean longshore-current. 2. Field Observations. *J. Geophys. Res-Oceans,* 94:(C12) 18031-18042.

Özkan-Haller, T. and J.T. Kirby (1999). Nonlinear evolution of shear instabilities of the longshore current: A comparison of observations and computations. *J. Geophys. Res-Oceans,* 104:(C11) 25953-25984.

Putrevu, U., J.T. Kirby, J. Oltman-Shay and T. Özkan-Haller (1998). On the viscous destabilization of longshore currents. In *Proc. 26th Int. Conf. Coastal Engng.,* 217-229.

Putrevu, U. and I. A. Svendsen (1999). Three-dimensional dispersion of momentum in wave- induced nearshore currents. *Eur. J. Mech. B/Fluids,* 83-101.

Slinn, D.N., J.A. Allen, P. A. Newberger, and R.A. Holman (1998). Nonlinear shear instabilities of alongshore currents over barred beaches. *J. Geophys. Res-Oceans,* 103:18,357-18,379.

PUBLICATIONS

Chen, Q., I.A. Svendsen (2001). Analysis of boundary error propagation in nearshore modelling. Jour. paper in preparation.

Chen, Q., I.A. Svendsen (2001). Effects of cross-shore boundaries on longshore current Simulations. ASCE, *Proc. Waves2001* conference.

Svendsen I. A., K. A. Haas and Q. Zhao (2001). Quasi-3D nearshore circulation model SHORECIRC, Version 2.0, CACR report 01-xx (In preparation).

Zhao, Q. and I. A. Svendsen (2001a). Numerical Analysis of Three-dimensional shear waves. Jour. paper in preparation.

Zhao, Q. and I. A. Svendsen (2001b). Three-dimensional lateral mixing in shear waves. ASCE Proc. Waves2001 conference.

Zhao, Q. and I. A. Svendsen (2001c). Quasi-3D Modeling of shear waves. Presentation at AGU Fall meeting 2001.